Elevated atmospheric CO_2 concentrations and climate change will affect our food's quality and quantity

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Greenhouse gas emissions are affecting the quantity and quality of our food in two ways. First, they are driving anthropogenic climate change, which decreases yields of major cereal crops in some regions. Increased temperatures, changes in precipitation patterns, increased ozone concentrations, and more frequent and extreme heatwaves, floods, and droughts can reduce crop yields, particularly in the tropics, with risks increasing with additional warming depending on the region.[1] Lower crop yields increase stunting and wasting, particularly in low-income and middle-income countries.[1] Second, increased concentrations of carbon dioxide (CO_2)—by directly affecting plants—worsen the nutritional quality of food by decreasing protein and mineral concentrations by 5–15%, and B vitamins by up to a 30%.[2–4] Higher CO_2 concentrations increase photosynthesis in C_3 plants (eg, wheat, rice, potatoes, barley), which can increase crop yields. But those increases come at the cost of lower nutritional quality as plants accumulate more carbohydrates and less minerals (eg, iron and zinc), which can negatively affect human nutrition.[5] Thus, accurately quantifying the effect of increasing CO_2 concentrations on human nutrition requires accounting for changes in the quantity and quality of crop harvests and diets and economic parameters (eg, food prices).

Decreases in the nutritional quality of crops related to CO_2 will exacerbate current challenges. As of 2017, 821 million people globally are food insecure, with 22% of children (151 million) stunted and 7·5% (over 50 million) wasted.[6] Micronutrient deficiencies cause a much larger burden of disease than food insecurity, with approximately 2 billion people having deficiencies in iron, zinc, and other micronutrients in 2003.[6] These deficiencies adversely affect cognitive development, metabolism, obesity, diabetes, and other health outcomes, potentially affecting health and welfare across the life course.

In *The Lancet Planetary Health*, Robert Beach and colleagues[7] accounted for projected climate change and fertilisation effects of CO_2 on crop yields and projected CO_2 effects on the concentrations of iron, zinc, and protein in crops between 2010 and 2050. Using a global economic model of the agricultural sector, they show that technological changes, market responses, and the fertilisation effects of CO_2 on yields are projected to increase the global availability of dietary protein, iron, and zinc. The authors then used two independently derived datasets of the effects of increasing CO_2 on crop quality: a subset of data restricted to edible tissues from Loladze (2014);[2] and data supporting Myers et al (2014)[3] with the wheat portion from Fernando (2013).[8] All the data were restricted to nitrogen (as a proxy for protein), iron, and zinc. The authors combined these datasets with economic projections of shifts in global diets, crop production, food prices, and income to project decreases in global availability of protein, iron, and zinc of 2·5–4·1% by midcentury, compared with estimates that ignore the effects of increased CO_2 on crop quality. These decreases are expected to slow progress in achieving reductions in global nutrient deficiencies, disproportionately affecting countries that already have high levels of nutritional deficieny.

Other modeling estimates also project negative effects of increasing atmospheric CO_2 concentrations on human nutrition by mid-century. Weyant and colleagues[9] accounted for climate change and dietary patterns to project that CO_2-induced reductions in the concentrations of zinc and iron in crops alone could induce 125·8 million disability-adjusted life-years globally, with southeast Asian and sub-Saharan African countries being most affected. Smith and Myers[10] assumed no changes in diets but accounted for decreases in nutrient content of crops to project that an additional 175 million people could become zinc deficient and an additional 122 million people could become protein deficient. Zhu and colleagues[4] estimate that 600 million people will be at risk later this century in countries with the highest levels of rice consumption and the lowest overall gross domestic product per capita.

Modeling efforts need to be expanded from focusing on iron and zinc to include other minerals essential for human nutrition, including calcium and magnesium, which also decrease in plants exposed to higher CO_2 concentrations.[2] The inclusion of these micronutrients is needed to quantify the total possible effect of

increasing CO_2 concentrations on human health. For example, about 3·5 billion people are at risk of dietary calcium deficiency, without considering the potential effects of increasing CO_2 concentrations.[11]

The magnitude of the health risks will be amplified when one considers the potential effects of increased concentrations of CO_2 on livestock, which contribute more than 15% of the global human protein supply. To quantify the trajectory of nutritional stress in cattle from reduction of nitrogen availability in grasslands caused by increasing CO_2 concentrations, Craine and colleagues[12] examined dietary quality over 22 years for US cattle, standardising for several factors, including forage quality, and showed that cattle have been increasingly protein-stressed, probably decreasing weight gain in cattle. The replacement costs of decreased protein provision were estimated to be the equivalent of US$1·9 billion annually.

Increasing research indicates that undernutrition will be the greatest health risk of increasing CO_2 concentrations and climate change. Solutions urgently need to be found to ensure the achievement of Sustainable Development Goal 2 on food security.

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IL's data, which were used by Beach and colleagues, are open access; he commented on the initial analyses by Beach and colleagues to ensure appropriate weighting and interpolating the results to various carbon dioxide concentrations, but had no further role in development of the manuscript. KLE declares no competing interests.

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